CHAPTER 3

POWER PLANT (AC): GENERATION SYSTEM

This chapter describes the function, operation, and maintenance of the power-generation system located in the engine room. Two 2-cycle auxiliary diesel engines are used to drive the two AC generators that generate power for all AC-operated equipment located on the 100-ton barge crane.

DIESEL ENGINE, 2-CYCLE

SPECIFICATIONS

This section describes the auxiliary diesel engines located in the engine room. The following illustration and table provide engine data.

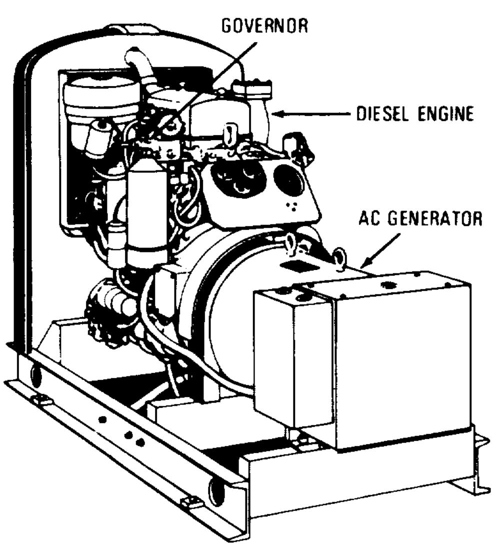
FUNCTIONAL DESCRIPTION

The 2-cycle diesel engine is an internal-combustion power unit in which the heat of fuel is converted into mechanical force and motion inside the cylinder of the engine. Air is compressed to a temperature high enough to ignite fuel sprayed directly into the cylinder where combustion and expansion actuate a piston.

In the 2-cycle engine, intake and exhaust take place during the compression and power strokes respectively. A blower forces air into the cylinders to expel the exhaust gases and supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports that are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports. The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the

Diesel Engine-Generator Set



ENGINE DATA

Manufacturer	Detroit Diesel Allison
Model	10235100
Type	2-cycle
Bore	4.25 inches
Stroke	5 inches
Cylinders	2 per engine
Compression	17 to 1
Total displacement	142 cubic inches
Fuel	Diesel
Direction of rotation	Right hand (viewed from front end)
Size (engine-generator set)	69 inches long, 32 inches wide, 48 1/2 inches high
Weight	2,110 pounds

charge of fresh air is compressed. Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector. The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure from combustion and expansion forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, allowing the waste gases to escape into the exhaust manifold. Shortly thereafter, the downward-moving piston uncovers the inlet ports and the cylinder is again swept with clean, scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft.

ENGINE COMPONENTS

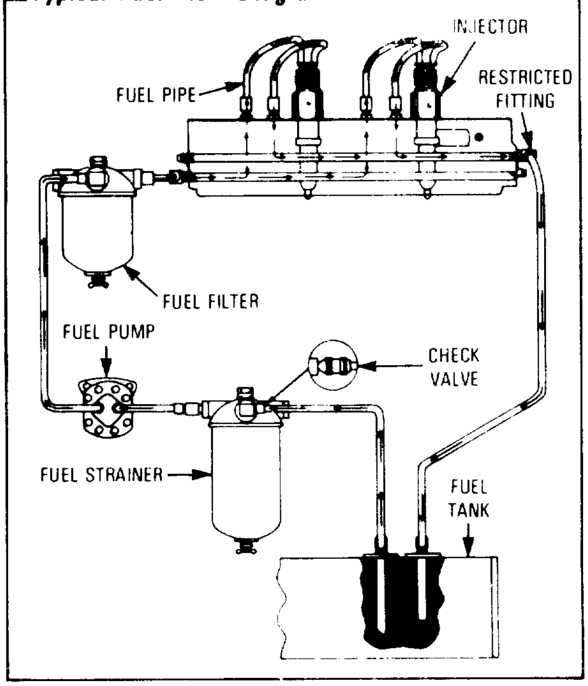
The diesel engine consists of the following basic systems: fuel, air, lubricating, engine cooling, electrical, and exhaust. These are described in detail as follows.

Fuel system

The fuel system consists of fuel injectors, pipes, manifolds, pump, strainer, filter, and necessary fuel lines. A restricted fitting is located in the cylinder-head, fuel-return, manifold outlet to maintain fuel pressure.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Upon leaving the pump under pressure, the fuel is forced through the fuel filter and into the fuel inlet manifold. See original inlet side of each fuel injector. The fuel is filtered through elements in the injectors and atomized through small jets into the combustion chamber. Surplus fuel, returning from the injectors, passes through the fuel-return manifold and connecting fuel lines back to the fuel tank. The continuous flow of fuel through the injectors helps to cool the injectors and remove air from the fuel system.

Typical Fuel Flow Diagram



The *fuel injector* combines all the parts necessary to provide complete and independent fuel injection at each cylinder. The injector creates the high pressure necessary for fuel injection, meters the proper amount of fuel, atomizes the fuel, and times the injection into the combustion chamber.

A positive displacement, gear-type *fuel pump* is attached to the cylinder block. It is driven by a helix gear on the engine balance shaft through an adapter and pinion gear.

A spring-loaded relief valve is incorporated in the pump body (normally in the closed position). It operates only when the pressure on the outlet side (to the fuel filter) becomes excessive due to a plugged filter or fuel line.

The fuel pump incorporates two oil seals. Two tapped holes are provided in the underside of the pump body, between the oil seals, to permit a drain tube to be attached. If fuel leakage exceeds one drop per minute, the seals must be replaced.

A replaceable element-type *fuel strainer* and *fuel filter* are used in the fuel system to remove impurities from the fuel. The strainer removes the larger particles, and the filter removes the smaller particles.

The fuel strainer and the fuel filter are basically identical in construction, both consisting of a cover, shell, and replaceable element. The fuel strainer functions under suction; the fuel filter operates under pressure.

Air system

The air system consists of a blower, air cleaner, air box drains, and crankcase ventilation system.

The *blower* supplies fresh air required for combustion and scavenging by forcing a charge of air into the cylinders. The charge of air sweeps all of the waste gases out through the exhaust valve ports. This leaves the cylinder tilled with fresh air for combustion at the end of each downward stroke of the piston. This air also assists in cooling the internal engine parts, particularly the exhaust valves.

Two hollow, three-lobe rotors are closely fitted in the blower housing, which is bolted to the cylinder block. The revolving motion of these rotors pulls fresh air through the air cleaner and provides a continuous and uniform displacement of air in each combustion chamber. The continuous discharge of fresh air from the blower creates a pressure in the air box (air box pressure).

The dry-type *air cleaner* consists of a metal wool cleaning element, saturated with oil and supported inside a housing over a hollow chamber. This serves as a silencer for the incoming air to the blower. Air drawn into the air cleaner by the blower passes through the metal wool, where foreign matter is removed, then down the central duct to the blower.

Air box drains allow drainage of condensate from the air boxes. During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil vapor, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through air box drain tubes mounted on the side of the cylinder block.

The air box drains are to be open at all times. With the engine running, a periodic check is recommended for air flow from the air box drain tubes. Liquid accumulation on the bottom of the air box indicates that a drain tube may be plugged.

Crankcase ventilation is required to remove harmful vapors from the engine. Harmful vapors that can be formed in the engine are removed from the crankcase, gear train, and valve compartments by a continuous, automatic ventilation system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the air box past the piston rings. The air sweeps up through the gear train compartment. It is admitted to the valve and injector rocker-arm compartment through a bored passage in the front end of the cylinder block and a mating passage in the cylinder head. Ventilating air in the valve and injector rocker-arm compartment is vented to the atmosphere through a vent pipe which is attached to the governor control housing.

Lubrication system

Lubricating oil is drawn from the engine oil pan into the inlet side of the oil pump. When the oil leaves the pump under pressure, it flows through a vertical front passage in the cylinder block into a bypass valve attached to the side of the block. Oil leaving the bypass valve flows up through a second vertical passage and enters the oil cooler element. From the cooler, the oil continues through a third vertical oil passage where it is diverted in two directions. One portion supplies lubrication to the front crankshaft main bearing and the front cam and balance shaft bearings. The remainder enters a horizontal oil gallery within the cylinder head.

In addition to supplying lubricating oil for the valve and injector rocker-arm assemblies, this oil in the cylinder head flows down through two vertical passages. This provides lubrication for the center and the rear main crankshaft bearings, in addition to the rear cam and balance shaft bearings. Oil for lubricating the connecting rod bearings flows through drilled passages in the crankshaft that connect with the front and center main bearings.

Drilled passages in the connecting rods provide lubrication for the piston pins. Cooling at the underside of the piston heads is provided by a spray nozzle pressed into the upper end of each connecting rod.

The gear train, including blower gears, and the blower front bearings are lubricated by oil that drains through openings in the front corner of the cylinder head and block onto the camshaft gear.

Lubrication for the blower rear bearing and governor weight assembly is provided by surplus oil returning from the cylinder head through connecting drilled passages in the cylinder block and blower rear end plate. Surplus oil returns to the engine oil pan through connecting passages in the cylinder block and blower rear end plates.

When the oil pressure within the lubricating oil pump exceeds the maximum value of the oil pump relief valve spring, the relief valve is moved off its seat. This permits the excess oil to return to the oil pan.

When the pressure at the inlet side of the bypass valve exceeds the maximum value of the bypass value spring, the ball within the assembly is moved off its seat. This permits the lubricating oil to bypass the oil cooler and enter the third vertical oil passage. This action thereby supplies lubricating oil to the various engine parts during the engine warm-up periods. It also ensures lubrication of engine parts in case the oil cooler becomes stopped up.

A bypass oil filter is attached to the side of the cylinder block to keep the lubricating oil free of dirt particles and sludge. The oil filter consists of an adapter, filter shell, center stud, replaceable-type filter element, retaining spring, and bolt. The oil filter element should be changed every time the engine oil is changed.

Cooling system

The heat exchanger core consists of a series of flat, water strut tubes attached to two round header plates. The core is mounted inside the expansion tank. It is sealed at each end with a seal ring and a flange to prevent the engine coolant from mixing with the raw water. The engine coolant which circulates through the engine cooling system flows around and between the core tubes as it leaves the water tank. The raw water, flowing horizontally through core tubes, lowers the temperature of the engine coolant.

To protect the heat exchanger core from the electrolytic action of the raw water, a zinc electrode is located in a tee fitting at the raw water inlet side of the core on certain engines equipped with this heat exchanger.

That portion of the tank located above the heat exchanger core provides a means of filling the engine coolant system, It also provides space for expansion of the coolant as the temperature rises. A vent tube near the top of the water tank vents the tank to the atmosphere.

The length of time a heat exchanger will function satisfactorily as a cooling unit will be governed largely by two factors. One is the kind of coolant used in the engine and the other the kind of cooling water (salt or fresh) pumped around and through the heat exchanger core by the raw water pump.

Clean water, plus a good commercial rust inhibitor, should be used as a coolant to prevent lime deposits in the heat exchanger core tubes as well as in the engine.

Enough coolant should be maintained in the engine to fill the cylinder block and head and to partially fill the water tank. Allow air space above the coolant in the tank for the increase in volume as the temperature of the coolant rises.

Electrical system

Each engine is equipped with a 24-volt electrical system. This system consists of a starting motor, a battery-charging alternator, a transistor voltage regulator, current regulator, and a cutout relay to protect the electrical system.

Exhaust system

The exhaust pipeline consists of a silencer (one for each engine) and the necessary exhaust line piping. The piping consists of 2 1/2-inch, standard weight, black iron pipe from the engine to the silencer and from the silencer out through the engine room roof. A flexible bellows is located between the engine and the silencer to provide for expansion and to minimize engine vibration. The silencer is a Maxim, Type MUL, which incorporates a nonresonant, side-tube arrangement to allow passage of the exhaust gases from one chamber to another.

INSTRUMENTS AND CONTROLS

The instruments and controls used to operate the engine are located as follows:

- The engine instrument panel is located on the engine.
- The engine control system panel is located on the bulkhead near the engine.
- The voltage control panel is located next to the engine control system panel.
- The AC generator switchboard is located adjacent to the DC switchboard in the engine room,

See Chapter 4 for a complete description of the AC generator switchboard.

Engine instrument panel

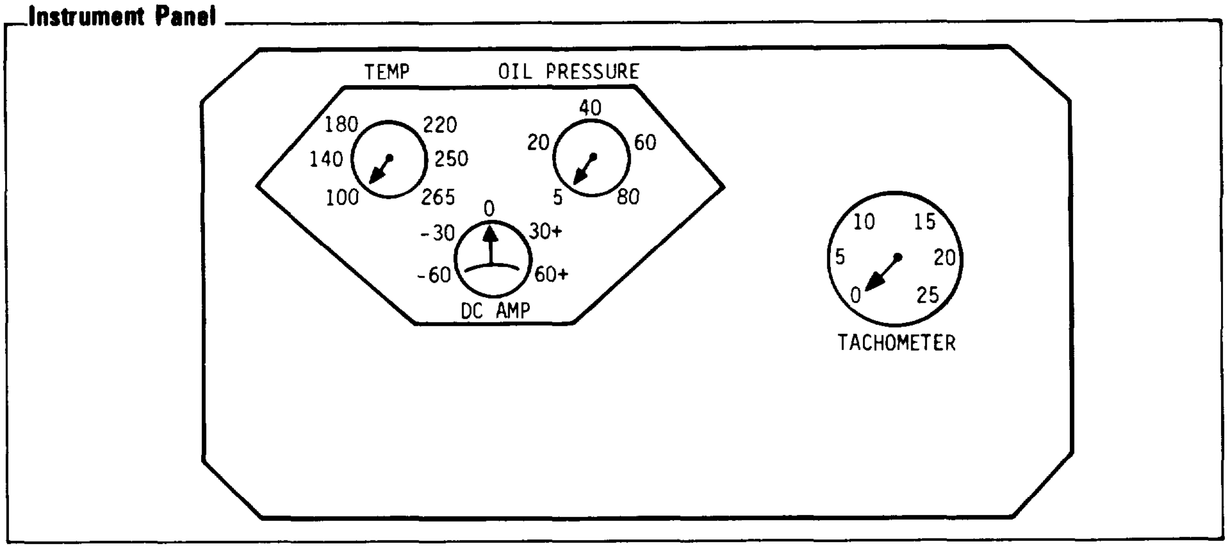
The *oil pressure gage* registers the pressure of the engine lubricating oil. As soon as the engine is started, the gage should start to register. If it does not register at least 18 psi within 10 to 15 seconds from start, the engine should be stopped and the cause determined and corrected before the engine is started again.

The *water temperature gage* registers the engine coolant temperature.

The *DC ammeter* reads the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery, replenishing the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in charge rate to the battery. The ammeter will not show a zero charge rate, however, since the regulator voltage is set higher than the battery voltage.

The *tachometer* is driven by the engine and registers the speed of the engine in RPM.

Instrument Panel



Engine control system panel

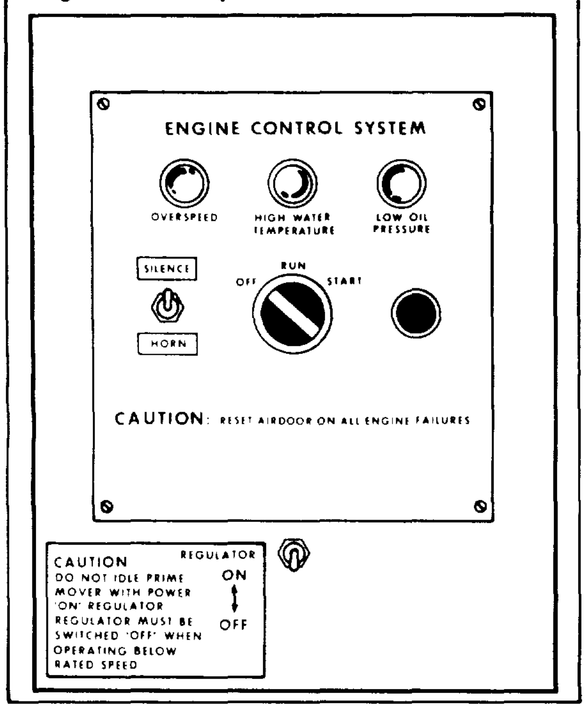
The *OFF-RUN-START switch* is used to start the diesel engine.

The *regulator ON-OFF switch* cuts in or cuts out the voltage regulator. It also allows the regulator to be out when the engine is operating below rated speed to avoid damage to the regulator.

The *SILENCE-HORN switch*, when in HORN position, allows the horn to sound. When placed in SILENCE position, it silences the horn.

The *alarm indicators* light up to indicate that an alarm. identified by the corresponding label, has occurred.

Engine Control System Panel



Voltage control panel

When the *CONTROL VOLTAGE switch* is on MANUAL, this switch allows voltage output of the AC generator to be adjusted using the MANUAL VOLT ADJUST rheostat. When on AUTO, the switch regulates voltage output that was set while in the MANUAL position. It also allows voltage output of AC generator to be adjusted from the AC switchboard.

The *MANUAL VOLT ADJUST rheostat* adjusts output voltage of the AC generator when the CONTROL VOLTAGE switch is in the MANUAL position.

This panel also contains the voltage regulator for the AC generator. Refer to the sections on the generator and the voltage regulator in this chapter.

ELECTRICAL STARTING EQUIPMENT

The electrical engine-starting equipment is listed and described as follows.

The *battery-charging alternator* provides electrical current. This is to keep the storage battery charged and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

The *regulator* is used to regulate the voltage and current output of the battery-charging alternator and to help maintain a fully charged storage battery.

The lead-acid *storage battery* has three major functions. It–

- Provides electrical power to start the engine.
- Stabilizes voltage in the electrical system.
- Furnishes current during failure of the alternator or battery voltage regulator.

The electric *starting motor* is a Bendix drive-type starter. It uses a solenoid for starting the engine when operating the OFF-RUN-START switch on the engine-control system panel. The starter motor becomes energized only when the control switch is in START position. When in START position, the auxiliary solenoid is energized. This causes the starter motor solenoid to energize through the auxiliary solenoid closed contacts. When this solenoid is energized, it in turn connects the batteries to the starter motor through the starter motor solenoid closed contacts. The motor then starts running, engaging the engine flywheel and starting the engine.

The engine automatic shutdown and alarm circuit is energized when the engine control switch is either in the START or RUN position. This circuit is described in the following section.

AUTOMATIC SHUTDOWN AND ALARM SYSTEM

The electrical shutdown mechanism will stop the engine automatically if one of the following conditions occurs:

- Lubrication oil pressure drops below a predetermined value.
- Engine coolant overheats.
- Engine overspends.

The shutdown mechanism works in conjunction with the alarm. The alarm sounds a horn to warn the operator that a malfunction has caused the engine to stop running. The horn will continue to sound until the operator moves the alarm toggle switch on the engine-control system panel to SILENCE The shutdown system consists of the following:

- LOW OIL PRESSURE switch connected into the engine oil gallery.
- WATER TEMPE RATURE switch connected into the cylinder head.
- FUEL OIL PRESSURE switch installed in the inlet side of the fuel oil filter.
- Hot wire relay.
- Shutdown solenoid attached to the blower air inlet housing and linked to a lever on the air shutoff valve shaft.
- Governor shutdown solenoid.
- Necessary components to automatically trip the AC generator main circuit breaker at the AC switchboard when reverse current is sensed at the AC generator output.

The electrical circuit is de-energized under normal operating conditions. After the engine is started, the LOW OIL PRESSURE switch opens when the lubricating oil pressure reaches approximately 10 psi and the FUEL OIL PRESSURE switch closes at approximately 12 psi fuel pressure. Since the fuel pressure builds up rapidly, the FUEL OIL PRESSURE switch could close before the LUBRICATING OIL PRESSURE switch opens and stops the engine. The hot wire relay, however, will delay the closing of the FUEL OIL PRESSURE switch several seconds. This is to enable the lubricating oil pressure to build up and open the LOW OIL PRESSURE switch contacts.

If the lubricating oil pressure falls below 10±2 psi, the contacts in the LOW OIL PRESSURE switch will close. Current will then flow through the hot wire relay to the shutdown solenoid. When the solenoid is energized, it releases the air shutoff latch, closing the air box door which causes the engine to stop. At the same time the LOW OIL PRESSURE indicator lights up on the engine control system panel, and the horn sounds to warn the operator. However, the few seconds required to heat the hot wire relay will provide sufficient delay to avoid an engine shutdown when the low oil pressure is caused by a temporary condition. Such a condition could be an air bubble or a temporary overlap in the operation of the LOW OIL PRESSURE switch and the FUEL OIL PRESSURE switch when starting or stopping the engine.

Two control relays, located inside the battery charger enclosure, also work in conjunction with the FUEL OIL PRESSURE switch on each engine. The relay for each engine is used to connect the engine batteries to the battery charger when the engine is not running. It is also used to disconnect the batteries from the charger and connect them to the engine alternator while the engine is running.

The watertemperature switch remains open during normal engine operation. When the engine coolant temperature rises to 206±5°F, the switch contacts close and activate the shutdown solenoid. The engine then stops, the HIGH WATER TEMPERATURE indictor lights up on the engine-control system panel, and the horn sounds.

If the engine speed exceeds the high speed setting of the governor (1,980 RMP), the OVERSPEED GOVERNOR switch closes and activates the shutdown solenoid. This causes the engine to stop, the OVERSPEED indicator to light up on the engine-control system panel, and the horn to sound. When the engine stops, the FUEL OIL PRESSURE switch opens and de-energizes the circuit.

The cause of any one of the abnormal conditions described above must be determined and corrected before the engine is started again. Also, the air shutoff valve must be manually reset in the open position before starting the engine.

If reverse current is sensed at the output of one of the AC generators, the reverse current relay associated with that generator closes. This energizes a shunt trip solenoid which causes the AC generator MAIN CIRCUIT breaker to trip at the AC switchboard.

MAINTENANCE

The remainder of this section discusses maintenance of the engine and its components.

Engine preparation for initial start-up

The following operations should be performed when preparing to start a new *or* overhauled engine or an engine that has been in storage.

Fill the *air cleaner* oil cup to the proper level with engine lubricating oil. Do not overfill.

Prepare the *cooling system* as follows:

- Install all the drain cocks in the cooling system. Drain cocks are removed for shipping.
- Open the cooling system vent.
- Remove the filler cap, and fill the cooling system with clean, soft water and a protective solution of high boiling point antifreeze. Keep the liquid level about 2 inches below the filler neck to allow for fluid expansion.
- Close the cooling system vent after filling.

Charge the engine *lubrication system* with a pressure prelubricator. The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one that has been in storage, may be insufficient for proper lubrication when the engine is started for the first time. The pressure prelubricator should be set to supply a minimum of 25 psi oil pressure for an immediate flow of oil to all bearings at the initial engine start-up. Make sure the oil supply line is attached to the engine before proceeding,

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use heavy-duty lubrieating oil, using the dipstick to check the oil level in the oil pan. Add enough oil to bring it to the FULL mark on the dipstick. Do not overfill,

If the pressure prelubricator is not available, fill the crankcase to the proper level with heavy-duty oil.

Preventive maintenance

The following table provides a timetable for engine lubrication and preventive maintenance services.

Engine Lubrication and Preventive Maintenance

ITEM OPERATION	TIME INTERVAL Hours of Operation							
	Daily	8	100	200	300	500	1,000	2,000
Engine oil	X							
Oil filter							X	
Coolant and filter	X					X	X	

Engine Lubrication and Preventive Maintenance (Continued)

ITEM OPERATION	TIME INTERVAL Hours of Operation								
	Daily	8	100	200	300	500	1,000	2,000	
Hoses						X			
Radiator							X		
Fuel tank	X					X			
Fuel strainer and filter					X				
Air cleaners		X				X			
Air box drains							X		
Ventilating system[1]									
Blower screen							X		
Starting motor[2]									
Battery-charging alternator		X	X		X			X	
Battery		X							
Tachometer drive		X							
Engine tune-up[3]									
Drive belts		X		X					
Overspeed governor						X			
Shutdown system				X					
Power generator		X		X					
Oil change							X		

[1] Clean crankcase breather cap whenever engine oil is changed.

[2] Lubricate oil wicks whenever starting motor is removed or disassembled. Lubricate Bendix drive mechanism when starting motor is removed for servicing.

[3] Tune up engine only as necessary to maintain satisfactory engine performance.

Corrective Maintenance

The following table gives information for exhaust analysis. It lists probable causes and suggested remedies based on the color of smoke being exhausted from the engine. Checks should be made with a minimum water-outlet temperature of 160°F.

Exhaust Smoke Analysis

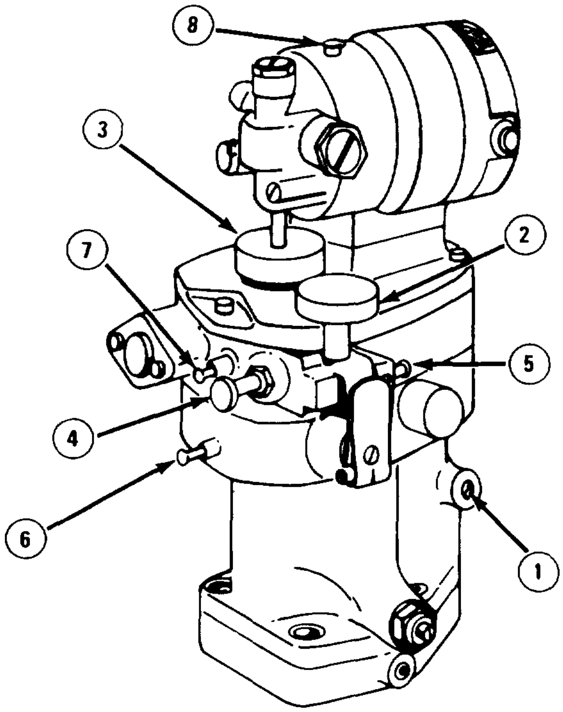
SIGN OF TROUBLE	PROBLEM DESCRIPTION AND PROBABLE CAUSE	REMEDY
Smoke, black or gray.	Incompletely burned fuel. High exhaust back pressure or a restricted air inlet, causing insufficient air for combustion and incompletely burned fuel.	Check for faulty exhaust or silencer obstruction (back pressure can be measured at exhaust manifold outlet with a manometer); replace defective parts.
		Check for clogged cylinder-liner ports, air cleaner, or blower air-inlet screen; clean these items.
		Check emergency stop-air valve to ensure that it is open; readjust if necessary.
	Excessive fuel or irregular fuel distribution.	Check for improperly timed injectors and improperly positioned injector rack control levers; time fuel injectors and governor to correct condition.
		Replace faulty injectors if condition persists after timing and tune-up.
		Check for cracked or broken injection spray tips.
	Improper grade of fuel oil.	Check grade of oil used; refer to fuel oil specification.
Smoke, blue.	Too much lubrication oil in cylinder.	Check for internal lubricating oil leaks.
Smoke, white.	Cylinders misfiring. Use of low-octane fuel.	Check for low compression, octane of fuel used, and water in oil.

GOVERNOR

SPECIFICATIONS

The governor is a variable-speed mechanical device. mounted on the engine and used to maintain a near-constant engine speed during load fluctuations. This is done by providing automatic fuel compensation to the engine during varying load conditions. Since the AC generator is directly coupled to the engine, constant speed is essential to produce constant frequency at the output of the generator. An engine speed of 1,800 RPM produces a generator-output frequency of 60 Hz. The governor is equipped with a speed adjusting motor that enables the operator (at the AC generator switchboard) to match the frequency of one generator to that of the other before synchronizing and to change the load after synchronizing. The following illustration and table provide governor data.

Governor (With synchronizing motor installed)



1 COMPENSATION NEEDLE VALVE
2 DROOP ADJUST KNOB
3 FRICTION DRIVE
4 LOAD LIMIT ADJUST SCREW
5 MAXIMUM DROOP SETTING SCREW
6 MAXIMUM SPEED ADJUST SCREW
7 MINIMUM DROOP SETTING SCREW
8 SYNCHRONIZING MOTOR

GOVERNOR DATA

Manufacturer	**Woodward Governor Company**
Model	**Hydraulic, speed droop-adjusting**
Type	**SG**
Torque output	***12 or 24 pounds/inch over 36°*** **travel of governor output shaft**
Operating speed	**2,400 or 3,600 RPM**
Control	**25% of normal speed**
Range adjustment	**1/2% to 7% over full 36° travel of governor output shaft**

FUNCTIONAL DESCRIPTION

The hydraulic, speed-droop-type governor is designed so that the operating speed decreases as the engine load increases. This increases the amount of fuel to the engine and increases its speed. Conversely, the governor operates at a higher speed as the engine load decreases, decreasing the amount of fuel to the engine and decreasing its speed. In this way, stability of the governed system is achieved, and division of load between parallel generators is made possible.

The governor incorporates a speed-stabilizer mechanism. Engine lubricating oil is admitted, under pressure, to an auxiliary oil pump in the governor. The auxiliary pump furnishes the necessary oil pressure to actuate the governor mechanism.

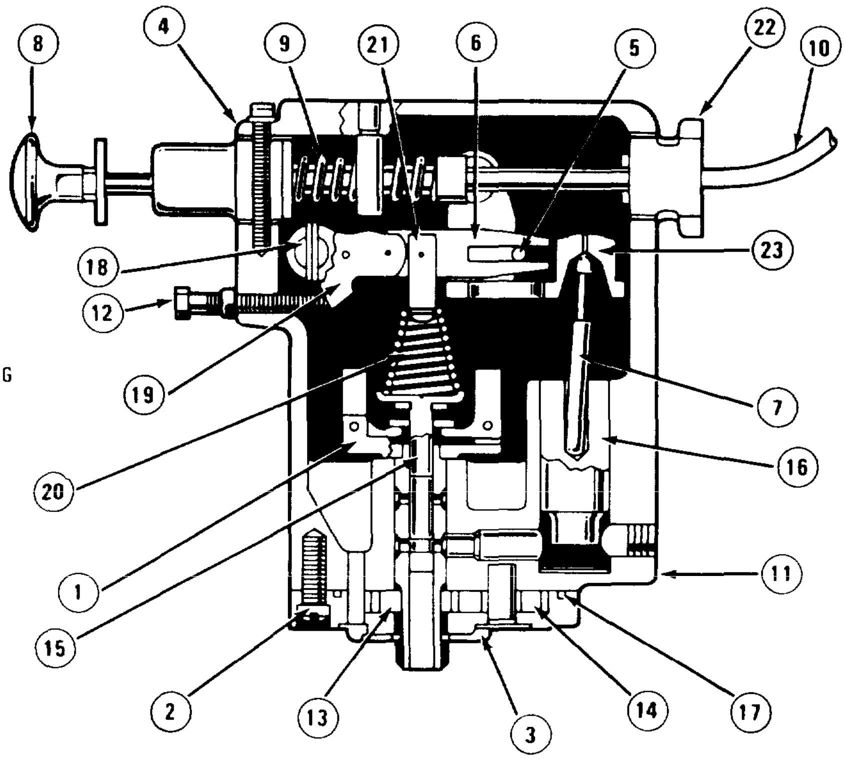
The governor is connected to the fuel injectors by a fuel rod that is attached to a lever on the injector control tube, The amount of fuel to the injectors is decreased by the action of a fuel rod spring and increased by the opposing action of a hydraulic power piston inside a cylinder. Admission of oil to the cylinder is controlled by a pilot valve. The pilot valve, in turn, is controlled by the fly-weights of the governor.

The two flyweights of the governor are mounted on a vertical shaft and driven, through a set of gears, by the upper rotor shaft of the blower. The centrifugal force of the rotating flyweights is opposed by a speeder spring. This spring is located on the vertical shaft between a spring fork at the top and the arms of the flyweights at the bottom. Compression of the speeder spring, which is controlled by the throttle, determines the speed at which the governor will control the engine.

For stability of operation (that is, without hunting), an adjustable, speed-droop mechanism is used in the governing system. Speed-droop adjustment is made through a slotted bracket attached to the terminal lever. Moving the droop-adjusting bracket in toward the engine increases governor droop. Moving it out, away from the engine, decreases the governor droop.

Sectional View of a Governor

1 BALL HEAD AND WEIGHT ASSEMBLY
2 BASE SCREW
3 BASE
4 COVER
5 DROOP-ADJUSTING BRACKET
6 FLOATING LEVER
7 FLOATING PIN
8 FUEL ROD KNOB
9 FUEL ROD SPRING
10 FUEL ROD
11 HOUSING
12 MAXIMUM SPEED-ADJUSTING SCREW
13 OIL PUMP DRIVE GEAR
14 OIL PUMP DRIVEN GEAR
15 PILOT VALVE PLUNGER
16 POWER PISTON
17 SEAL RING
18 SPEED-ADJUSTING SHAFT
19 SPEED-ADJUSTING LEVER
20 SPEEDER SPRING
21 SPRING FORK
22 SUBCAP
23 TERMINAL LEVER



When starting a cold engine, several cranking periods may be required for the lubricating oil pressure to become great enough to operate the governor and open the throttle so the engine can start. Since such a delay in starting is considered objectionable, the starting time can be reduced by pulling out on the fuel rod knob. The outward movement of the fuel rod takes control away from the governor.

Since the engine can be stopped by pushing in the fuel rod knob, the fuel rod can also act as a stopping device. Considerable force must be exerted to do this, since the oil pressure against the power piston must be overcome.

In addition to its function of holding the engine speed constant under varying loads, the hydraulic governor acts as an automatic shutdown device in case of lubricating oil pressure failure. Should the engine fail to supply oil to the governor, the servo piston will drop, letting the fuel rod return to the no-fuel position and shutting down the engine.

Governor drive

The governor drive shaft is splined to fit into the engine drive. The governor is mounted vertically and has a 3/8-inch external drain line provided to connect a 1/4-inch pipe-tapped hole in the lower end of the governor cover.

The governor drive shaft is rotated clockwise (when viewed from above). The governor oil inlet and relief valve assembly are on the left, when viewing the governor form the nameplate end.

Synchronizing motor

A synchronizing motor is mounted on the governor to provide a remote speed control. It enables the operator at the AC switchboard to match the frequency of one engine-driven generator to the other generator before synchronizing and to change the load distribution after synchronizing.

The motor is of the split-field, series-wound, reversible type. There is a slip coupling between the motor shaft and synchronizer-adjusting gear. This allows the engine operator to adjust speed by turning the speed-adjusting screw on the governor. A friction coupling is incorporated in the cover assembly to permit overtravel of the motor without damage.

Speed droop

The speed-droop adjustment can be set to automatically divide and balance the load between engines when electrically connected in parallel. Droop is incorporated in the governor through a linkage that varies the compression of the speeder (speed-adjusting) spring as the terminal shaft rotates. Increased fuel reduces spring compression, reducing the governor speed setting accordingly. The unit will also gradually reduce its speed as load is applied. This relationship between load and speed acts as a resistance to load changes when the unit is interconnected with other units, either mechanically or electrically. As droop is reduced toward zero, the unit becomes able to change load without changing speed.

The load is distributed between the two generators by speed and voltage adjustment through operation of the governor speed-control switch and voltage-control rheostat respectively.

Load limit

A load-limit adjustment hydraulically limits the load that can be applied to the engine by restricting the angular, terminal shaft rotation of the governor. This consequently restricts the amount of fuel supplied to the engine.

GOVERNOR ADJUSTMENTS

Three kinds of adjustments need to be made on the governor.

Initial engine start-up

Start the engine. Then position the speed-adjusting shaft for the desired running speed, and allow the engine to warm up. If the engine surges during warm-up, remove the governor cover assembly while engine is running, and adjust the droop bracket and pin toward maximum position (away from governor ball head).

Preliminary speed-droop adjustment

When the engine is warmed up, adjust the droop bracket and pin as much toward minimum as possible while maintaining steady speed.

Manually move the engine fuel linkage to temporarily increase engine speed. If the engine returns to the original steady speed, the adjustment is satisfactory for most single-engine installations. If the engine speed does not settle out, increase the droop slightly (an approximately 1/16-inch movement of bracket) and test again. Continue to increase the droop until operation is satisfactory.

Final speed-droop adjustment

For single-engine operation, set the speed-droop bracket as near minimum as possible (consistent with satisfactory performance) to have the least decrease in speed as load is added to the engine.

For parallel-engine operation, both engine-generator sets are equipped with a speed-droop govenor. Both governors must therefore be set to the same no-load and full-load droop setting. This will allow the load to be balanced on parallel units without changing the system frequency.

Set the droop sufficiently high (towards maximum) to secure satisfactory load division between generator sets. If the load does not divide properly, increase droop on the engine taking too great a portion of the load. Increasing droop setting will also prevent interchange of load between generator sets.

GENERATOR

SPECIFICATIONS

The two AC generators provide AC power to all AC-operated equipment on the floating barge crane. Each generator is driven by a diesel engine, which is speed-controlled through a hydraulically operated governor to provide a constant frequency output. The output voltage of each generator is set by a rheostat at the voltage control panel and regulated by its own voltage regulator. The following table gives detailed data on the generator.

Generator Data

Manufacturer	Kato Engineering Company
Model	30-SX9E
Type	Single-bearing
Power output	30 kw
Voltage	240/277 VAC
Cycles	60 Hz
Speed	1,800 RPM
Phase	3-phase
Windings	Series Delta
Size (generator)	31 inches long, 21 inches wide, and 16 1/2 inches high

FUNCTIONAL DESCRIPTION

The AC generation system consists of a brushless exciter mounted within the generator frame and a saturable transformer voltage regulator mounted in the voltage control panel.

The saturable transformer voltage regulator uses a solid state preamplifier for voltage error detection and control. It includes a series-boost circuit that increases regulator output during periods of high line-current demands such as when motors are started or shorts occur in the load. An automat ic voltage-adjust potentiometer permits the user to change the generator output voltage over a range of ±10 percent of 240 VAC.

The generator output voltage is produced in the generator stationary armature (stator). Voltage is induced into the stator windings by a rotating magnetic field. This field is produced by the turning generator field. For the generator field to become magnetized and produce a rotating magnetic field, a DC voltage (excitation) must be fed to the generator field coils and the generator rotor must be turning. The excitation voltage is supplied by the exciter. The exciter field poles retain some permanent magnetism, thus producing a magnetic field in the exciter. When the generator is started, voltage is induced in the exciter armature windings, fed to the rotating rectifiers, rectified, and fed to the generator field. The generator field then becomes magnetized and produces a rotating magnetic field. Control of the degree of magnetism of the generator field, and thus the voltage induced into the generator stator windings, depends on the voltage from the exciter. The exciter voltage is controlled by the voltage regulator, which supplies and controls the field current fed to the exciter field.

MAINTENANCE

Preventive maintenance

As necessary carry out the following inspection and cleaning procedures:

- Inspect lead wiring for cracked insulation and loose terminals.
- Inspect control equipment for loose mounting hardware.
- Clean the outside of the generator assembly and ventilating screens.
- Clean and/or dry the inside of the generator assembly when dust or moisture is present.

When inspection determines that cleaning is necessary, make certain that generators are not running and are tagged OUT OF SERVICE before performing the following procedure:

- Wipe loose dirt from exterior painted surfaces of the generator with a clean cloth. Remove stubborn accumulations of dirt with a detergent or solvent. Clean all ventilating ports with a vacuum cleaner, or use filtered compressed air at a pressure of 25 to 40 psi.

- Clean inside of generator with a vacuum cleaner, or dry filtered compressed air at a pressure of 25 to 40 psi. Remove accumulations of grease and dirt from windings with naptha.
- Clean electrical contacts and terminals with an approved contact cleaner. Do not file contacts.

The generator is equipped with shielded ball bearings. Periodic replenishment of grease is normally not required. A good time to inspect bearings is during major overhaul of the generator or diesel engine. Then either replace or repack the bearings depending on their condition.

If bearings are to be repacked, fill approximately half full. Use a good grade of ball bearing grease recommended for electrical motor service. The grease should be capable of retainng satisfactory lubricating qualities from a temperature of 240°F down to the lowest ambient temperature surrounding the generator.

The generator windings are protected from dampness by strip heaters, one set for each generator. Strip heaters, 120-VAC, 1-phase power, are available at the strip heater distribution box. The heaters for each generator can be turned on by operating the associated switch at the distribution box. Winding resistance can be checked before placing the generator in operation To do this, use the ground-detect system PUSH-TO-TEST push button on the AC switchboard. The GROUND-DETECT SYSTEM lights will reflect the condition of the windings.

Winding insulation resistance can be tested with a hand-cranked megger of not over 500 volts. When meggering any generator winding, remove all connections to associated components, such as the voltage regulator, rectifier bridge, or load. When reconnecting the leads, make sure that all connections are made correctly.

If the insulation fails to meet the test standards (1 megohm minimum), the generator can be heat-dried with a warm air oven, heat lamps, or strip heaters. The temperature should not exceed 150°F.

The generator windings can also be dried with internal heat by using a variable source of direct current. Check for excessive accumulation (pockets) of water on generator windings. Dry as much as possible with compressed air before applying internal heat. Then proceed as follows:

- Remove generator terminal box cover. Disconnect all generator stator leads (1 through 12) from voltage regulator leads and load lines.
- Connect generator stator leads to short-circuit the stator windings.
- In one of the generator leads, insert an ammeter of sufficient size to read full-load generator current.
- Disconnect exciter field leads from F+ and F-terminals on the voltage regulator, and connect a variable source of direct current to the exciter field leads.
- Operate the generator at normal speed. Supply just enough excitation to cause rated current to flow in the generator stator windings.
- Operate for sufficient time to ensure thorough drying of the windings. This can be determined by stopping the generator periodically and checking the insulation resistance of the windings. Check insulation resistance at l-hour intervals. Terminate the drying-out process when measured resistance is within test standards and shows little change over a 2- to 4-hour period of operation.

NOTE: When reconnecting the generator leads, make sure they are connected correctly, otherwise the phase rotation will be affected.

Corrective maintenance

The following chart shows what steps to take in troubleshooting the generator.

Troubleshooting Chart : Generator

SYMPTOM	PROBABLE CAUSE	REMEDY
No voltage output.	Open circuit breaker.	Check and reset circuit breaker.
	Open circuit in exciter field.	Check out continuity of shunt field and leads to voltage control (use ohmmeter or Wheatstone bridge). If open in field coils, remove exciter field field assembly and return assembly to factory for repair.
	Loss of residual magnetism in the exciter field poles.	Adjust manual-adjust potentiometer to full resistance. Flash field by making a flash connection of DC across terminals F1 to F2.
	Open circuit in stator winding.	Check for continuity in windings. Return to factory for repair if open.
	Malfunction of automatic voltage regulator.	See troubleshooting of voltage regulator in this chapter.
	Short-circuited generator output leads.	Clear lead to restore voltage buildup.
	Open in rotating rectifiers.	Check rotating rectifiers; replace if open.
	Open in alternator field.	Check for continuity; return rotor to factory for repair if field coils are open.
	Shorted rotating rectifiers.	Check for shorts; replace if faulty.
	Shorted exciter armature.	Check for short; if faulty replace.
	Shorted leads between exciter armature and generator field.	Test and repair.
Low voltage output.	REGULATOR ON-OFF switch in OFF position.	Position to ON.
	Improper adjustment of VOLTAGE ADJUST rheostat.	Adjust rheostat. (See Voltage Regulator in this chapter.)
	High-resistance connection; connections will be warm.	Tighten connections.
	Shorted field.	Test field coils for possible short by checking resistance with an ohmmeter or resistance bridge. Return rotor assembly to factory for repair if alternator field coils are shorted.
	Weak field due to operating in warm temperature.	Improve the ventilation of generator. Field current can be increased, providing the generator temperature rating is not exceeded.
	Improper speed of engine-driven generator set due to defective governor, ignition system, or carburetor.	Check and correct deficiencies. (See Diesel Engine or Governor in this chapter.)

Troubleshooting Chart : Generator (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Fluctuating voltage.	Voltage regulator not operating properly.	Check regulator. (See Voltage Regulator in this chapter.)
	Engine speed fluctuating.	Check engine governor. (See Governor in this chapter.)
	Loose terminal or load connections.	Tighten connections.
	DC excitation voltage fluctuating.	Check DC excitation circuit. Correct any defects.
High voltage output.	Overspeed.	Correct speed of engine by adjusting governor. (Refer to Governor in this chapter.)
	Improper connection of generator.	Reconnect generator correctly.
	Improper adjustment of VOLTAGE ADJUST rheostat.	Adjust rheostat. (See Voltage Regulator in this chapter.)
Overheating.	Clogged ventilating screens and air passages.	Clean all screens and air passages.
	Dry or defective bearings.	Lubricate dry bearings; replace if defective.
	Generator field coils shorted or grounded.	Test field coils for shorts; replace if rotor is shorted or return to factory for repair.
Vibration.	Defective or dry bearings.	Lubricate dry bearings; replace if defective.
	Misalignment of generator and engine.	Align generator set.
	Generator not properly mounted.	Check mounting; correct defective mounting.

VOLTAGE REGULATOR

SPECIFICATIONS

The voltage regulator is used with the AC generator to maintain the generator output voltage within ±2% of the preset value, from no-load to full-rated load. It is also capable of providing more than 200 percent rated short-circuit current for starting loads. The regulator obtains its power from the generator output voltage. The following table gives detailed data on the voltage regulator.

Voltage Regulator Data

Manufacturer	Kato Engineering Company
Type	Kamag No 13683
Sensing	120/240-volt, 50- to 60-Hz, 1-phase
Power output	100-VDC, 2-amp
Current boost	200%
Regulation	±2%
Size (voltage control panel)	24 inches high, 20 inches wide, and 9 1/4 inches deep
Weight	About 60 lb

FUNCTIONAL DESCRIPTION

The voltage regulator consists of a highly saturable transformer and a solid state preamplifier. The regulator also incorporates voltage rheostat multiterminal switch (RMS) sensing and current boost. This latter feature provides short circuit current boost to ensure good starting characteristics. Shown is the closed loop control diagram of the generator-regulator system into basic blocks.

The generator provides a means of converting mechanical energy from an engine to electrical energy. To increase the generator ability to perform as an infinite bus, a voltage regulator is used as a generator field exciter. With external constant field excitation, the generator terminal voltage would be the inherent regulation, ranging from 10 to 50 percent. The voltage regulator improves regulation to ±2 percent or better under rated, full-load conditions.

Voltage and current are combined magnetically in a saturable transformer. The saturable transformer has a control winding (C1, C2) to vary the output as an inversely proportional power amplifier. For example, increasing control signal results in reduced output.

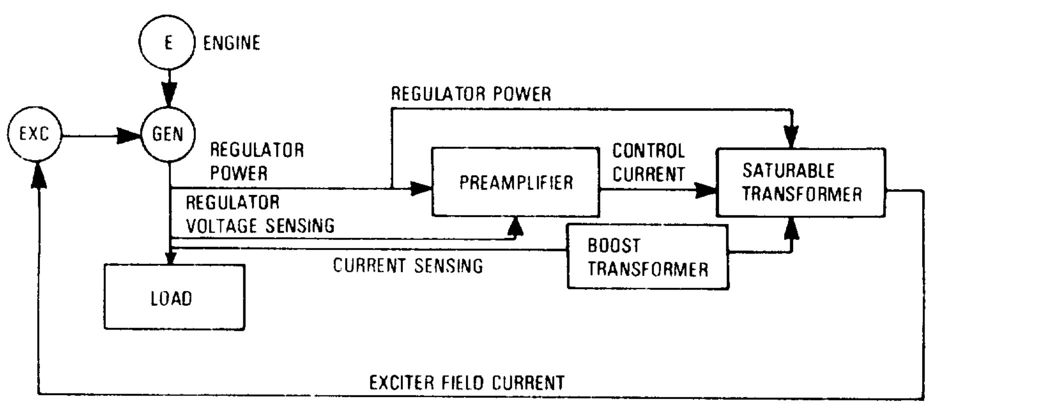
Winding (H1, H3) provides the power to TS1. Power is obtained from the generator output. Linear reactor (LI) is a series, current-limiting reactor that supplies reasonably constant current to TS1 under no-load conditions.

Current boost winding (E, F) is the load current boost. Since generator field excitation is nearly proportional to load current, an increasing load will provide additional current to TS1. This results in nearly the exact increase in field excitation.

Control winding (C1, C2) provides a means for voltage adjustment and compensation for circuit tolerance and increases in field power due to thermal effects.

Winding (X1, X3) is the output AC, which is rectified by a full-wave diode bridge (BR1). The DC output of the rectifier bridge provides field excitation.

Closed Loop Control of Generator and Voltage Regulator



Voltage output adjustment

The generator output voltage level can be adjusted as follows:

Step 1. With the generator running at rated speed (1,800 RPM) and the CONTROL VOLTAGE switch on the voltage control panel positioned to AUTO, adjust the VOLTAGE ADJUST rheostat (R18) for 240-VAC output. If that voltage level cannot be obtained, adjust R18 to halfway range; then proceed to the following step.

Step 2. Adjust VOLTAGE RANGE ADJUST potentiometer R19 for 240-VAC output. Adjustment of potentiometers R18 and R19 back and forth may be necessary for the correct 240-VAC output level.

Voltage stability adjustment

If, during operation, voltage output oscillates or poor response occurs when the load is varied, adjust for stability as follows:

Step 1. With voltage output adjusted to 240 VAC, adjust STABILITY ADJUST potentiometer R8 (located on the circuit card) until voltage output is stable at both no-load and full load.

Step 2. Refer to Generator in this chapter for frequency setting and load application.

MAINTENANCE

Preventive maintenance

Preventive maintenance consists of periodic inspecting and cleaning. The voltage regulator should be inspected and cleaned approximately four times a year as follows:

Step 1. Make sure that the generator is shut down; then remove the five clamps and open panel door.

Step 2. Inspect lead wires and terminal connections. Repair any frayed or worn lead wire insulation. Tighten any loose terminal connectors. Clean excessive dirt from the lead wires with clean cloth.

Step 3. Clean dirt from the voltage regulator with a vacuum cleaner or with filtered, compressed air at a pressure of 25 to 40 psi.

Step 4. Check the regulator for loose mounting bolts or nuts. Tighten any loose connections.

Step 6. Close the door and replace the five clamps before starting the generator.

WARNING: Avoid exposure to dangerous voltage. Do not attempt to repair or clean parts within the terminal box when generator is running.

Corrective maintenance

The following troubleshooting chart pinpoints specific problems, probable causes, and corrective actions. Refer to diagrams at the end of this chapter for schematics of the voltage regulator and preamplifier assemblies (pages 3-25 through 3-28).

Troubleshooting Chart Voltage Regulator

SYMPTOM	PROBABLE CAUSE	REMEDY
No generator output voltage.	No residual magnetism in exciter field.	Disconnect F+, F- leads at regulator and flash field with about 12 VDC.
	Shorted or open exciter armature, generator field or generator armature windings.	Measure resistance of windings as check for open windings. Check resistance to ground as check for shorted windings. If windings are open or shorted, return defective part to factory or authorized local repair shop.
	REGULATOR ON-OFF switch in OFF position.	Position switch to ON.
	Exciter rectifiers open.	Test; replace defective rectifiers.
Generator output voltage low.	VOLTAGE ADJUST (R18) not properly adjusted.	Adjust potentiometer. Refer to procedures outlined in operating instructions.
Generator output voltage low but controllable at no-load.	Regulator or generator not connected correctly.	Connect as shown on generator set wiring diagram.
	Diesel engine under speed.	Increase speed to generator set.
	Defective voltage regulator.	Check sensing, error detector, and amplifier circuits.

Troubleshooting Chart : Voltage Regulator (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Generator output voltage low at no-load. No voltage control and exciter residual at about 25 percent of nominal.	Exciter field defective or regulator disconnected or defective.	Check connections to voltage regulator. (Refer to generator set wiring diagram.) If connections are correct, disconnect F+, F- leads at regulator and flash field with 12 VDC. If voltage rises to nearly normal, regulator is probably defective and should be repaired or replaced. If voltage does not rise when field is flashed, check exciter field resistance. Repair defective exciter field.
Generator output voltage low (50 to 90 percent rated no-load) and no regulator control.	Low engine speed.	Check engine speed. Increase to rated value of generator.
	Generator or regulator not connected correctly.	Check connections. (Refer to generator set wrong diagram.)
	Defective regu!ator.	Excite separately with 12 VDC connected to exciter field leads F+, F-. If voltage rises, regulator is probably defective. lest regulator components: repair or replace regulator.
	Open VOLTAGE ADJUST (R18) or VOLTAGE RANGE ADJUST (R19) potentiometers.	Test; replace if defective.
Generator output voltage high but controllable at no-load.	Engine speed high.	Reduce speed of generator.
	Open sensing or shorted VOLTAGE ADJUST (R 18) or VOLTAGE RANGE ADJUST (R19) potentiometers. Defective error detector or amplifier.	Check sensing circuit for poor connections. Check sensing transformer for open or shorted windings. Check VOLTAGE ADJUST potentiometers; replace defective components. Test components located on printed circuit board.
Poor regulation. Generator output voltage normal at no-load, but collapses or drops under load. Load removal results in nominal voltage.	Engine speed drops due to governor not functioning properly.	Adjust governor.
	Generator or regulator disconnected.	Check generator set wiring diagram; reconnect if disconnected.
	Unbalanced load.	Balance load (see Generator in this chapter).
	Regulator defective.	Test by connecting separate excitation voltage to terminals F+, F-, about 30 to 60 VDC depending on kw load and power factor. If voltage is nearly normal, voltage regulator is probably defective. Replace or repair.

Troubleshooting Chart : Voltage Regulator (Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Poor regulation. Generator output voltage normal at no-load, but collapses or drops under load. Load removal results in nominal voltage (Continued).	Generator defective.	Test as described above. If near-normal power does not result when unit is separately excited, check generator connections and test winding resistance. Also test rotating rectifiers in exciter assembly.
Poor response on load application.	Same as "poor regulation" above.	Same as "poor regulation" above.
	REGULATOR STABILITY ADJUST (R8) requires adjustment.	Adjust as described in operating instructions for voltage stability adjustment. Normally a regulator that is stable at no-load will remain stable when steady-state load is applied.
Voltage fluctuates, oscillates, or hunts.	Engine speed fluctuating.	Check repair defective governor.
	Regulator STABILITY ADJUST (R8) requires adjustment.	Adjust as described in operating instructions for voltage stability adjustment. Normally a regulator that is stable at no-load will remain stable when steady-state load is applied.

Voltage regulator assembly removal

The voltage regulator assembly can be removed from the voltage control panel as follows:

Step 1. Remove the five clamps from the panel door, and open door.

Step 2. Free the electrical cable by removing the two clamps.

Step 3. Disconnect the cable from the terminals on the back of the door.

Step 4. Remove the four nuts and washers; then remove regulator assembly from panel.

Step 5. Disconnect the reactor cable from the transformer.

***Step* 6.** Disconnect wiring from the terminals on the side of the preamplifier subassembly.

Step 7. Remove four nuts, washers, and screws; then remove the preamplifier subassembly.

Voltage regulator components testing

Follow these procedures for testing the various components of the voltage regulator. When testing components connected in a circuit, care should be taken that other components in the circuit do not affect readings.

CAUTIONS: Meggers and high-potential test equipment should be used with care. Incorrect use of such equipment could destroy the rectifiers, transistors, and capacitors in the regulator.

When testing insulation resistance of generator windings with the megger, first disconnect leads between regulator and generator.

During normal operation, the *rectifier* sometimes develops small brown surface marks. These usually do not affect rectifier operation. To test the rectifier, follow these steps:

Step 1. Connect an ohmmeter or 3-volt test light across the rectifier. Observe the ohmmeter reading or, if a test light is used, observe if bulb lights.

Step 2. Reverse the leads. Again, observe the ohmmeter reading or, if a test light is used, observe if bulb lights.

Step 3. A good rectifier will have high resistance in one direction and low resistance in the opposite direction. If a test lamp is used, the bulb should light in the direction of low resistance and should not light in the direction of high resistance. If a low resistance is indicated in both Steps 1 and 2, the rectifier is probably shorted. High resistance in both Steps 1 and 2 indicates an open rectifier.

Capacitors can be checked on a capacitor bridge to measure capacitance and leakage. Capacitance should not vary more than ±10 percent from rated values.

If an ohmmeter is used, connect across the capacitor and set to a high-resistance scale. The meter should initially indicate low resistance and should then gradually increase until capacitor is fully charged.

Typical defects of the *saturable transformer* are open or shorted windings. Open windings can be determined by disconnecting the transformer from the circuit and then testing continuity of the windings. Shorted windings generally can be detected by checking resistance of the transformer windings with the winding resistance of an identical transformer known to be in good condition.

Check the secondary voltages of the power *transformer* with rated voltage on the primary winding. Measured voltages, taken when a transformer is unloaded, run up to about 10 percent higher than those taken when the transformer is wired into its circuit. Typical transformer defects are shorts between windings, open windings, and shorted turns. These usually can be detected by checking resistances and voltages. When the transformer overheats and the existence of shorted turns cannot be proved by resistance measurement, check the no-load alternating current in the primary winding. This excitation current will be excessive if there are shorted turns.

Current transformers have a fixed ratio of current between primary and secondary currents. The ratio between these currents is determined by the turns ratio. The following test can be made for shorted turns:

Step 1. Load the generator to produce primary current in the transformer.

Step 2. Measure the secondary current.

CAUTION: Do not open the secondary current of a current transformer while the circuit is energized.

The ratio of primary to secondary current is approximately the same as the ratio of secondary turns to primary turns. If the secondary current is considerably less than it should be, shorted turns are indicated.

Check the resistance values of *potentiometers* and *resistors* with an ohmmeter. Potentiometers and adjustable resistors should be checked over their full range. Take care to avoid damage to the fine wire when setting adjustment bands on ajustable resistors. The adjustment band should be loosened until it slides freely on the resistor tube. Typical defects are open or short-circuited resistors.

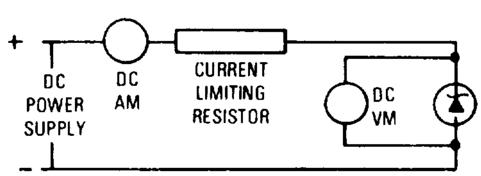
Silicon transistors can be tested with a 3. volt test light as detailed in the following transistor test chart. The test-by-test light method will normally indicate if a transistor is open or short-circuited. Remove the transistor from the circuit to prevent other components in the circuit from affecting the readings. The light indications listed in the following table will be observed if the transistor is not shorted or open. The following illustrations show the location of base, emitter, and collector lead.

Transistor Test

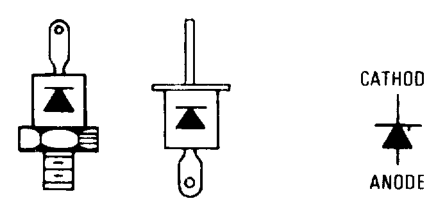
TYPE TRANSISTOR	TEST LAMP NEGATIVE LEAD CONNECTED TO-	TEST LAMP POSITIVE LEAD CONNECTED TO-	LIGHT INDICATION
NPN	Base	Emitter	No light
NPN	Base	Collector	No light
NPN	Emitter	Base	Light
NPN	Collector	Base	Light
PNP	Base	Emitter	Light
PNP	Base	Collector	Light
PNP	Emitter	Base	No light
PNP	Collector	Base	No light

A *zener diode* can be checked with an ohmmeter in much the same way as for a normal rectifier, or a battery check can be performed. If a DC power supply having a low ripple is available, the actual operation of the zener can be checked. Referring to the test setup illustrated in the figure showing the zener diode test, the voltage across the diode will increase until it reaches the zener voltage. As the DC input voltage is increased, the voltage across the diode will remain constant and the current through the diode will increase rapidly. Do not exceed the current rating of the diode.

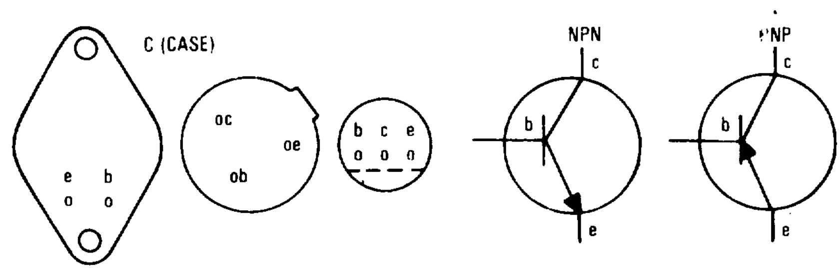
Zener Diode Test



Silicon Rectifier



Silicon Transistor (Physical and electrical diagrams)



Voltage and resistance measurements

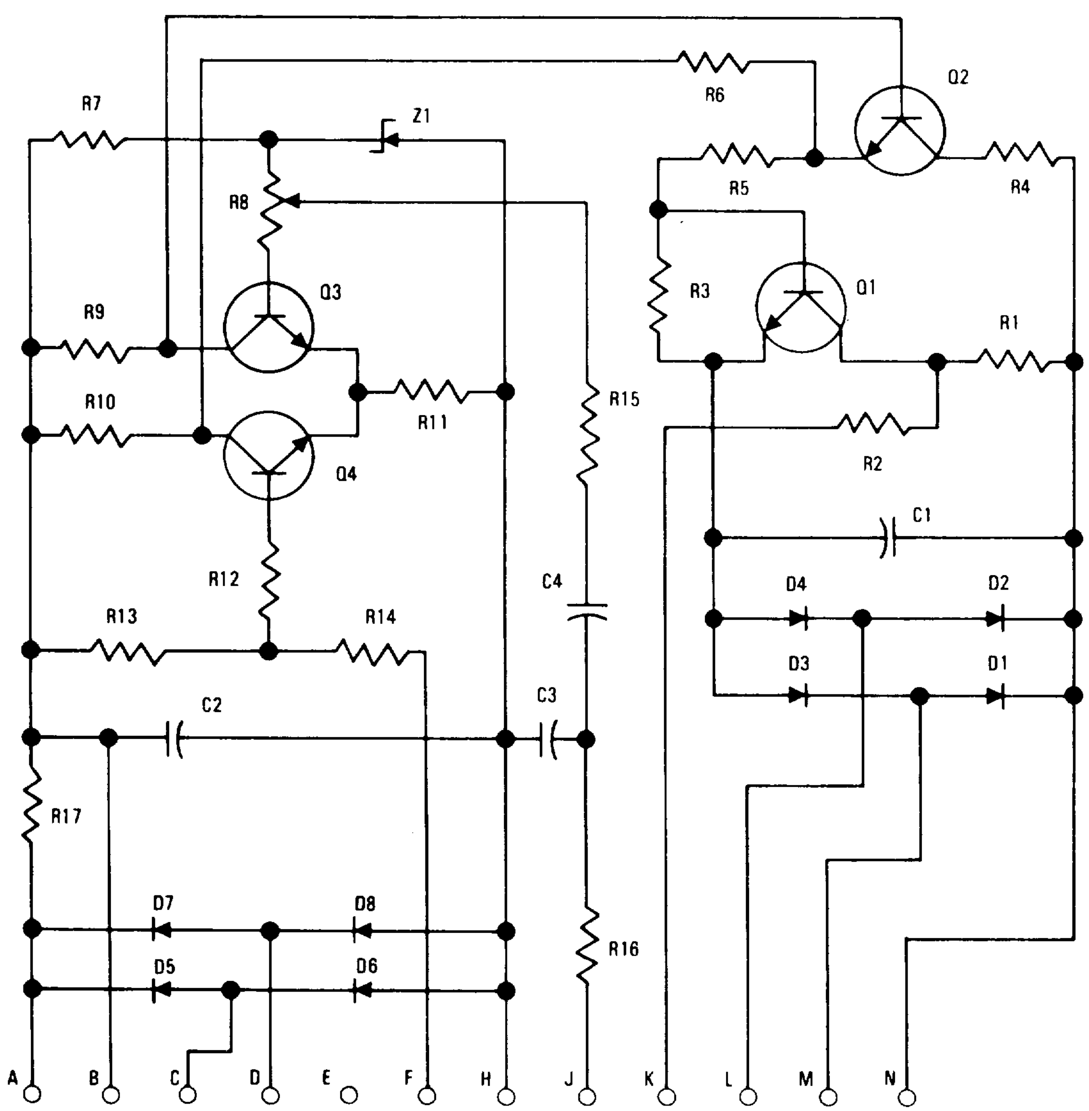
Voltage and resistance values across the voltage regulator circuits are outlined in the following table of regulator voltage and resistance measurements. The measurements are taken with a Multimeter. Voltage measurements will be taken with no-load on the generator and generator output voltage so adjusted that 135 VAC will appear between regulator terminals L and N (Saturable Transformer, Schematic 3). To take resistance measurements, disconnect wires to regulator terminals F+, F-, L, N, T1, T2, T3, and T4. Leave wires on terminals 7 and 8.

Mechanical assemblies of the voltage regulator are illustrated on the following pages.

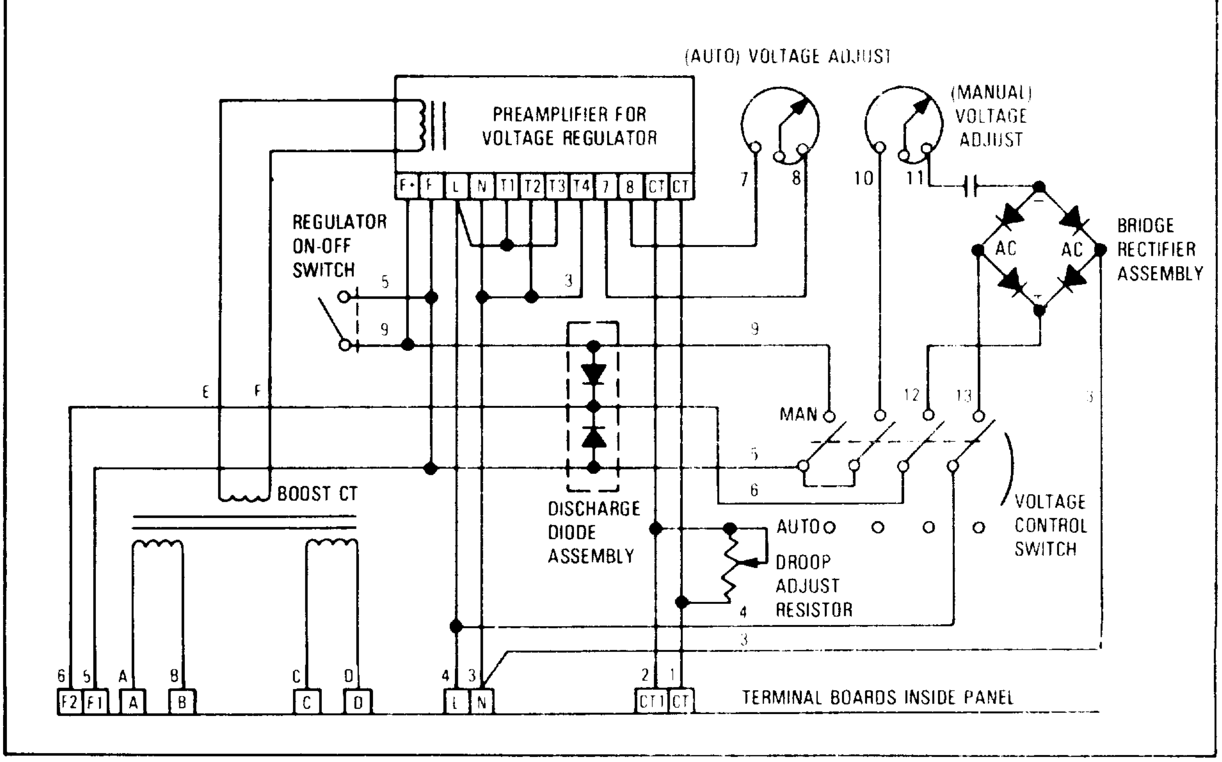
REGULATOR VOLTAGE AND RESISTANCE MEASUREMENTS

STEP	POINT OF MEASUREMENT	TYPICAL READING
	(Refer to Schematic 1)	(May vary slightly)
1.	Printed circuit board terminals A to B	260 ohms
2.	Printed circuit board terminals F to H	0-1500 ohms depending on voltage adjustment setting
3.	Printed circuit board terminals C and D	30 VAC, 6.5 ohms
4.	Printed circuit board terminals L to M	30 VAC, 6.5 ohms
5.	Printed circuit board terminals K (C-) 10 N (c+)	3.5 VDC
6.	Printed circuit board across Z1	Zener voltage 8.2 VDC
7.	Printed circuit board, junction of resistors R13, R14 to printed circuit board terminal H	8.2 VDC nominal; varies with changes in sensing and setting of voltage adjustment
	(Refer to Schematic 2)	
8.	Regulator terminal board, terminals L TO N	135 VAC
9.	Regulator terminal board, terminals T1 to T2	120 VAC
10.	Regulator terminal board, terminals T3 to T4	120 VAC
11.	Regulator terminal board, terminals F+ to F-	13 VDC
	(Refer to Schematic 3)	
12.	Saturable transformer TS1, terminals H1 to H3	28 VAC, 6.5 ohms
13.	Saturable transformer TS1, terminal H1 to regulator terminal L	107 VAC
14.	Saturable transformer TS1, terminals X1 to X3	20 VAC, 6.5 ohms

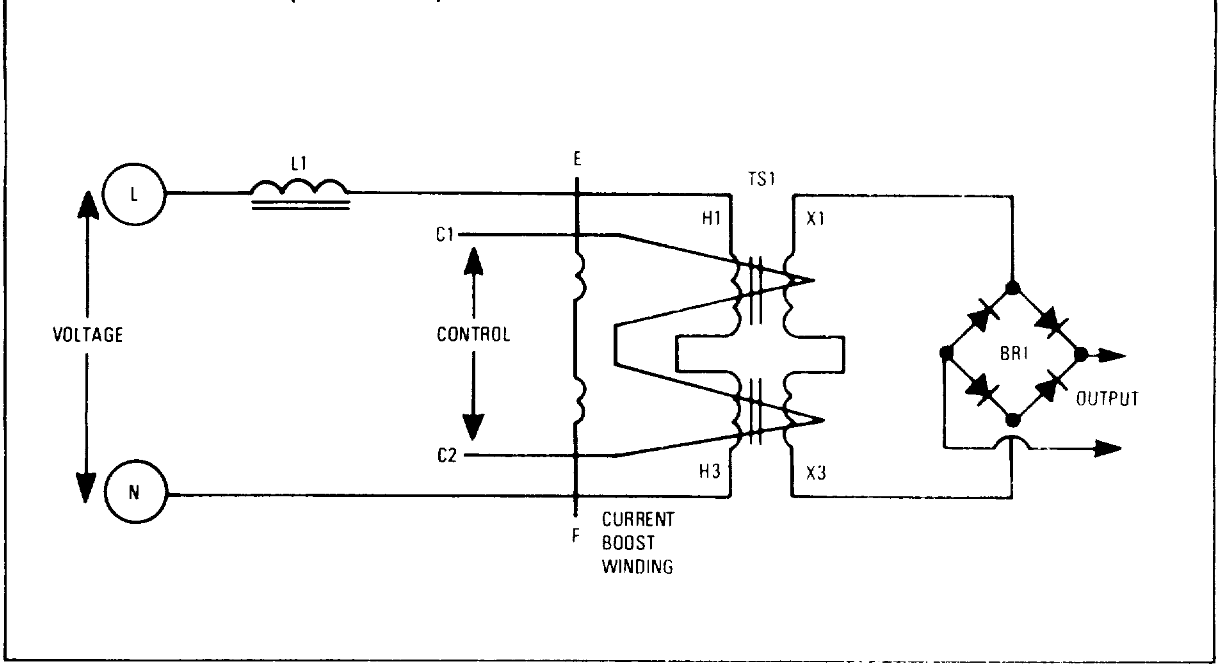
Preamplifier of Voltage Regulator (Schematic 1)



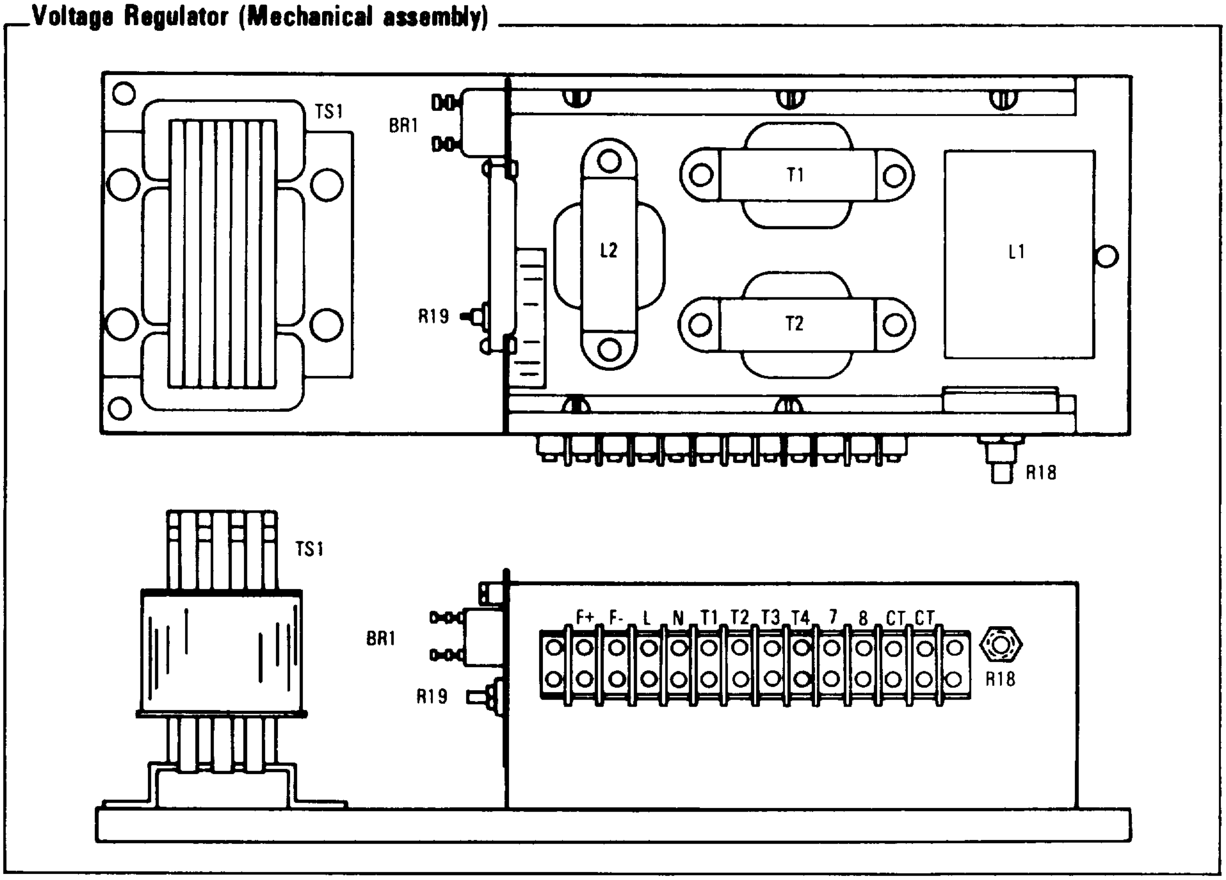
Voltage Regulator (Schematic 2)



Saturable Transformer (Schematic 3)



Voltage Regulator (Mechanical assembly)



Preamplifier of Voltage Regulator (Mechanical assembly)